CALiPER

Roundtable Report

December 2007

DOE Solid-State Lighting CALiPER Program

2007 Roundtable

Prepared for the U.S. Department of Energy by
Pacific Northwest National Laboratory

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Bob Berger, Independent Testing Laboratory
James Brodrick, U.S. Department of Energy
Kevin Dowling, Philips Solid State Lighting
Mike Grather, Luminaire Testing Laboratory
Ian Lewin, Lighting Sciences, Inc.
Cameron Miller, National Institute of Standards and Technology
Mia Paget, Pacific Northwest National Laboratory
Eric Richman, Pacific Northwest National Laboratory
Heidi Steward, Pacific Northwest National Laboratory
Fred Welsh, Radcliffe Advisors
Yuqin Zong, National Institute of Standards and Technology

Thanks to all for such an enriching, constructive event.

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COMMENTS

The Department of Energy is interested in feedback or comments on the materials presented in this Workshop Report. Please write directly to James Brodrick, Lighting R&D Manager:

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DOE Solid-State Lighting
CALiPER Program

2007 CALiPER Roundtable Proceedings

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Building Technologies Program
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Introduction

On November 27, 2007, the Department of Energy's Building Technologies Program hosted a Roundtable discussion for continued collaboration among standards setting organizations and the Solid-State Lighting (SSL) industry. Twenty-nine representatives from the Illuminating Engineering Society of North America (IESNA), National Institute of Standards and Technology (NIST), National Electrical Manufacturers Association (NEMA), American National Standards Institute (ANSI), various industry testing laboratories, manufacturers, and research laboratories gathered in Bethesda, Maryland to provide updates on progress and discuss issues related to SSL testing and LED standards development.

James Brodrick of the U.S. Department of Energy welcomed the Roundtable participants, setting the tone for an energetic and productive working session. The CALiPER (Commercially Available LED Product Evaluation and Reporting) Roundtable was designed to specifically address the status of DOE SSL product testing, solicit input to guide the DOE CALiPER test program, provide input to standards groups, and suggest additional testing standards needed. The CALiPER Roundtable is the third gathering hosted by DOE to provide leadership and support to accelerate the LED standards development process.[1]

While the primary focus of the Roundtable was the working sessions involving active participation of all attendees, a few presentations were given at the outset of the morning and the afternoon to provide background information and material for reflection. These presentations are summarized briefly below. The highlights of the working sessions are then summarized, with a synopsis of the issues surrounding SSL testing that were identified and options and solutions that were discussed.

Summary of Presentations from the CALiPER Roundtable

Standards Activity and Progress

Eric Richman of Pacific Northwest National Laboratory (PNNL) summarized the current status of the development of LED standards and test methods, driven by issues surrounding energy efficiency, life, thermal effects, and color characteristics. A number of SSL/LED-specific performance standards and test methods are currently under development, including:[2]

- ANSI C78.377 Specification for Chromaticity of White SSL Products
  (expected publication: January 2008)
- IESNA LM-79 Electrical and Photometric Measurements of SSL
  (expected publication: January 2008)
- IESNA LM-80 Lumen Depreciation of SSL (Lifetime)
  (expected publication: January 2008)
- IESNA RP-16 (addendum) Nomenclature/Definitions
- ANSI C82.XX1 Electronic Drivers for SSL (Power Supply)
  (in draft review by working group)
- UL 8750 (currently - Outline of Investigation)

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[1] For more information about the DOE's Solid-State Lighting market based programs, visit: http://www.netl.doe.gov/ssl/.

[2] For more information about Solid-State Lighting standards, visit http://www.netl.doe.gov/ssl/standards_dev.html, and download the DOE's fact sheet, "LED Measurement Series: Solid-State Lighting Standards," http://www.netl.doe.gov/ssl/PDFs/SolidStateLightingStandards.pdf.

CALiPER Testing Program Progress and Uncertainties

The DOE CALiPER Program tests commercially available SSL Products. Mia Paget of PNNL provided a quick synopsis of the testing program progress to date and of the variability seen in CALiPER testing. Most basic CALiPER testing to date has been based on the IESNA LM-79 draft standard for electrical and photometric measurements of SSL luminaires and replacement lamps. Additional CALiPER testing has included "in situ" tests, lumen depreciation testing of luminaires, and other exploratory testing.[3]

One of the purposes of the CALiPER program is to provide feedback toward the development, refinement, and adoption of credible, standardized test procedures and measurements for SSL products. With this objective in mind, the CALiPER program has examined various factors surrounding LM-79 testing in integrating spheres and goniophotometers, resulting in a brief report, "DOE Solid-State Lighting CALiPER Program--2007 Initial Summary Report on Testing Variability and Repeatability." [4]

This study of variability in CALiPER testing aimed to identify and investigate sources of uncertainty in testing. It examined variability in results across different units of a product, variability in results depending on testing methods (integrating sphere versus goniophotometry), and differences in photometric measurements between testing laboratories. Overall, the results of this study show limited variability, on average, in all cases, on par with variability expectations for similar testing of luminaires using more traditional light sources. For specific cases where variability was observed, possible sources of uncertainty are suggested, and were introduced as input for discussion in the CALiPER Roundtable.

LED Device Level Testing Research

Current standardized testing methods (such as CIE 127:2007) do not address issues surrounding testing of high power LED devices. Measurement techniques for these devices are being studied at the National Institute of Standards and Technology. Yuqin Zong (NIST) presented a simple approach for high-power LED measurement based on mounting the device on a metal-core printed circuit board attached to a temperature-controlled heat sink. Using this configuration, tests can be conducted with both pulse methodologies (before thermal equilibrium is reached) and direct current (DC) operations (after thermal equilibrium is reached), yielding comparable results. Initial tests have led to additional questions to consider, such as: what temperatures should be used for these tests; where should temperature measurements be taken; and can LEDs be binned at a temperature other than room temperature? Upcoming studies and discussions with stakeholders will hopefully provide answers.

NIST/NVLAP Process & LED Specific Activities

The National Voluntary Laboratory Accreditation Program (NVLAP) provides a process for accreditation of testing and calibration laboratories based on ISO/IEC standards and linked to NIST measurement research. Cameron Miller (NIST) presented an introduction to the NVLAP procedure for applying for accreditation and to the program-specific application for testing energy efficient solid-state lighting products. NVLAP accreditation is a fee-based system, available to any qualified laboratory, involving requirements for a documented quality system, on-site assessment, and proficiency testing. The "NIST Handbook 150-1A – NVLAP ENERGY EFFICIENT Solid-State Lighting Products" is expected to be available as soon as LM-79 and LM-80 (currently IESNA draft standards) are published (around February 2008).

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[3]For more information about the DOE's CALiPER testing program, visit: http://www.netl.doe.gov/ssl/comm_testing.htm.

[4] This report, DOE Solid-State Lighting CALiPER Program--2007 Initial Summary Report on Testing Variability and Repeatability," can be obtained through request to: calipersupport@pnl.gov.

Will there be an LED Testing Capabilities Gap?

Heidi Steward (PNNL) examined the question of expected SSL testing needs, in light of CALiPER testing and testing which can be expected as the ENERGY STAR® Criteria for SSL comes into effect in the fall of 2008. Testing SSL products requires performing absolute photometry on luminaires, which is somewhat different from relative testing typically done on more traditional sources. Today in the U.S., a handful of laboratories have the equipment and experience needed to perform SSL product testing credibly, and no labs can currently be 'accredited' for SSL testing, because the testing standards must be published before accreditation process can be set in place and initiated. Keeping in mind the considerable increase in SSL testing predicted for 2008 and 2009, there will be both a challenge and an opportunity for industry. In acknowledgement of the concept that LED photometry is both an art and a science, testing laboratories will need to brace for these upcoming needs: adequate measurement equipment and instrumentation, appropriate training, and experience with SSL testing.

Q & A Session with Independent Testing Labs

Two leaders from independent lighting testing laboratories answered numerous questions about SSL testing. Mike Grather, Luminaire Testing Laboratory, and Bob Berger, Independent Testing Laboratory, described many of the subtleties and difficulties involved with testing SSL products in both integrating spheres and goniophotometers.

Working Sessions: Examining SSL Testing

A key objective of the Roundtable was to actively engage this collection of experts through discussion to help guide the CALiPER program, to provide input to standards groups, and to suggest additional testing standards needs. In the morning breakout sessions, the groups were asked to brainstorm about issues related to SSL testing and prioritize those issues, covering photometric performance testing in general, at the LED device level, at the SSL luminaire level, and with respect to reliability. In the afternoon session, the group as whole examined the issues that were identified and discussed possible solutions and paths forward to address these issues.

The following bulleted lists summarize the concerns that were identified and solutions that were suggested or discussed. The various areas of concern are often overlapping, but for clarity, they are divided into five bulleted lists in the following pages:

A. General SSL Photometry (applying to both luminaires and devices)
B. Luminaire Photometric Performance Testing
C. LED Device Level Testing
D. Reliability Testing
E. Other Testing (glare, applications, safety, etc.)

The order of these concerns and solutions does not relate to the priority of the issues, because there was no clear decision across the board on which issues are more important than others. Nevertheless, across the three breakout groups, it appeared that device level testing—particularly surrounding temperature measurements used to assess product reliability—was very high on the list of priorities.

A. SSL Testing Concerns and Solutions: General SSL Photometry

- SSL/LED testing may require specific reference light sources.
  - NIST can calibrate both directional and non-directional sources.
- SSL/LED testing may require greater specular accuracy of the measurement detector/system.
  - For absolute measurements, specular accuracy is more critical.
  - Consider investigating LED sources with potentially peculiar outputs.
  - Study the use of spectral radiometers as opposed to other instruments.
  - Study the types of detectors used for different tests and possible impacts.
- Is there a need to simplify testing (speed=money), and what are options for doing so?
  - Can a choice be made between goniophotometry and integrating sphere (particularly for narrow beam source testing)?
  - The distribution of the luminaire is critical for LED products (in addition to flux).
  - Sphere: Provides lumen totals and color values, not only intensity distributions; may be quicker
  - Gonio: Provides lumen totals and intensity distribution, not color values; may require more time.
  - Consider adapting goniophotometers to do gonio-spectroradiometry.
  - Consider other new measurement techniques such as imaging.
  - Consider testing mechanisms involving simulated fixtures.
  - Upcoming LM-77 may enable one-shot zonal distribution measure.
- Recognize that measurement uncertainty exists.
  - Uncertainty – 5% - ISO 17025.
  - Further analyses of testing uncertainty would be useful, but uncertainty calculations can be time consuming for testing laboratories and costly.
  - Measurement tolerances need to be better understood, including how they affect ratings that may be close to upper or lower bounds (e.g., CCT).
- SSL testing strategies may impact other lighting sources and standards.
  - LED luminaire (system) efficacy vs. CFL lamp efficacy (*not*) taking fixture into account.
  - Will luminaire (system) efficacy concepts push back to traditional standards?

B. SSL Testing Concerns and Solutions: Luminaire Photometric Performance Testing

- Standards details or other guidance is needed surrounding SSL goniophotometry testing procedures.
    - Determine an appropriate number of measure points for goniophotometry tests. (Should it be close to 1% spread for LED products?)
    - Consider differences between old vs. new goniophotometry products. Old processes may use discrete stop-measure-move process. Newer configurations may be able to take averages across discrete measurement points. This may produce better accuracy.
    - LM-79 or subsequent guidelines need to explain when <5% gonio test measure spread is needed and provide specific guidance on the % spread to be used in specific applications. (LM-35 has some more details on these applications.)
    - Provide cautions on capturing the entire field of view for directional luminaries.

- Integrating sphere testing subtleties and further detailed guidance is needed.
    - Provide guidance about the directionality of sources in sphere measurements. (Do directional calibration sources need to be specified for directional product tests?)
    - Provide more details addressing different sphere testing scenarios.
        - Directionality of sources/reference standards
        - Size of sphere vs. size of sample
        - Setup, orientation of sample, baffle
        - Calibrations (procedures, frequency, scenarios, etc.)
        - Tips for controlling temperature in spheres during luminaire testing
- Electrical testing
    - In pulse-testing, scaling is difficult (e.g. current control), PWM is used effecting electrical requirements and impacting testing.
- Sample sizes
    - Determine appropriate sample sizes for different forms of testing.
    - Increase sample sizes when possible.
    - Perform repeatability and round-robin testing with larger sample sizes.
    - Samples from different batches, different bins are needed.

C. SSL Testing Concerns and Solutions: LED Device Level Testing

- LED device level testing methods and standards are urgently needed.
- Different domains may need different methods for LED device testing.
  - Heat sink temperature control (as described by Yuqin Zong)
  - Environmentally controlled sphere
  - Temperature correlations at the device level, such as T_j (junction temperature), or T_B or
  - Device efficacy standard needed
  - Consider concerns related to testing during manufacturing of devices
    - Bridge device use vs. quick easy test
    - Standard die measures
      - Useful to OEMs
      - Binning outputs – op. temp/lumens
- Taking device level temperature measurements needs further specification, study, and understanding.
  - Temperature controlled measurement pulse test standard
  - T_{CASE} test point defined in relation to T_J
  - T_J (or other clearly defined temperature measurement point) characterized with respect to efficacy & color
  - Establish clear instructions concerning how temperature measurements for junction or case or board temperatures are conducted
    - Location(s)
    - Gauge of wires/instruments
    - Attachments (pressure, solder, thermal paste, etc.)
    - Equilibrium
- Device level color shifting behaviors need to be characterized.
  - Study and characterize color shift temperature correlation
  - Consider a standard method for a color shift derating curve
  - Provide mechanisms to address color shift and color shift over time
  - CCT specification (distance from black-body curve and normalization)
- Need methods to ensure that substitution high power LEDs can be purchased reliably
- LED device (chip) change over time can affect otherwise consistent luminaire (in addition to other changes in the luminaire) – some issues are connected to ENERGY STAR qualification.
  - UL defines critical component changes that require re-test. ENERGY STAR has a similar approach.
  - It is not easy to identify items that, if changed, will not effect luminaire capabilities/output.
  - Luminaire manufacturers may not notice product drift if chips are changing from supplier.
  - Supplier bin variability may effect luminaire consistency.
  - Will this require suppliers to provide further chip specs or run documentation?
  - Will this require initial testing be based on multiple production lot samples? If not available (e.g., qualified on pre-production run), consider requiring submission of production run tests to verify later.
  - If verification of qualifications is by random testing there needs to be a challenge process, especially if single samples are tested.

D. SSL Testing Concerns and Solutions: Reliability Testing

- LM-80 is per device but other tests must be conducted for the luminaire lifetime.
  - Specifications or guidance will be needed at both device and luminaire level.
  - Like with L_{70}, how far can efficacy degrade and be OK?
- Many high priority issues stem from questions surrounding temperature measurement points and their relationship to life testing.
  - Specific and consistent definitions of temperature measurement points are needed (see useful application notes from some device manufacturers).
  - Temperature measurement points must be correlated to junction temperatures, or curves provided that allow luminaire manufacturers to make design decisions based on temperatures measured at these points.
  - Solutions for specifying valid TMP points or options for arrays should be investigated and developed.
  - Reference specification pushing requirement that devices and packages be manufactured with a labeled temperature measurement point.
  - Develop instructions or recommended practice/guidance for luminaire manufacturers as to how to use these points for relative luminaire lumen depreciation testing.
- Luminaire reliability (life) depends on more than lumen depreciation; multiple luminaire failure modes may exist.
  - What is failure? Definitions (particularly at the system level) are needed.
  - Identification and characterization of failure modes is needed (catastrophic, gradual, etc.).
  - What are failure mechanisms (solder joints, lenses, drivers, materials, etc.)?
  - How many of a set need to be tested to characterize failures?
  - What is driver stability over time? Can we characterize driver failures?
  - How does long-term driver stability affect output of device over time?
  - What accelerated life testing is conducted or can be conducted at the luminaire level? What do we learn from that?
  - What is lifetime variability? There may be a wide ‘family’ of depreciation curves.
- Further communication is needed to help luminaire manufacturers understand how to build off reliability testing done on chips.
  - Correlation L0-L1-L2 (chip – package – luminaire).
  - Better communication/reporting on statistical distributions. What is the confidence level?
  - Explaining/understanding depreciation curves.
  - What impacts LED device reliability aside from lumen depreciation?
  - What accelerated life testing is conducted or can be conducted at the device level? What do we learn from that?
- *In Situ* style testing can provide more insight into reliability.
  - Using application-dependent conditions from UL extreme situations may allow evaluation under worst case conditions, providing a reliability envelope.
  - Temp testing should mimic true applications instead of standard temp tests, to simulate ‘real world’ operation (e.g. refrigerated case, high industrial applications, outdoor luminaries).
  - Long term (depreciation) testing under *in situ* conditions should be conducted.
  - The relative energy efficiency of operation using dimmers should be studied (also comparing dimmers in device vs. old style dimmers).
  - RGB luminaires may perform differently *in situ*.

E. SSL Testing Concerns and Solutions: Other Testing

- Application issues (not seen as high on priority lists)
  - Niche application issues
    - Provide guidance or standards for ENERGY STAR directionality requirements (measurement methods, distances, zero angles).
  - Simulated fixture – where stabilized – LM-20; LM-66
  - Outdoor fixtures – wide thermal variance color/efficiency
  - Multi-shadowing
  - Color shadowing – chromaticity variance
  - Application illuminance
  - New applications
    - New applications – IES file info vs. software to use it
    - New applications – IES file cannot model intensity measures
    - How to test new applications in labs?
- Glare
  - Glare IES RP-1 intensity only
  - Glare total area of brightly lit cd/m2
  - Glare – what is array? – avg. vs. max. luminance
  - "One man's sparkle is another man's glare"
- CIE 127 implementation issues for high brightness LEDs
  - Angles, test distances, testing arrays, alignment on optical axis versus axis of peak intensity
- Health & Safety
  - Action spectra
    - Circadian rhythms
    - Phototoxicity
    - How to apply study results?
  - Photoluminescence
    - LEDs may not activate safety lighting
  - Flicker – safety/health – minimum rate? Frequency?
  - UL process: Hurry up! – meeting logistics
  - Photobiological effects of LEDs (safety, blue light hazard increasing)
    - Device
    - Luminaires with optics

Wrap-up Remarks

Following the day of discussion, three experts were asked to comment: What were key insights, points of consensus, and next steps for the industry, standards committees, and testing labs?

Ian Lewin, Lighting Sciences, Inc., sees this as a very exciting time—the lighting industry is back where it was in the 1940s when fluorescent light came in, testing a new type of product. Lewin reminded us that the switch from relative to absolute photometry driven by LEDs is a major shift. With relative photometry, errors in mismatch of sensors to response curves cancel with the two related measures. Absolute measure does not hide these potential differences. The IES expectation is +/- 2% for measurements of relative luminaire efficiency. To achieve similar levels of variability with absolute photometry is great. Lewin notes three particular areas needing work:

- Stabilization: Settling to within a percentage shift may not be sufficient, possibly a measure of actual +/- shift would be more appropriate in LM-79 and LM-80.
- Defining angular steps for narrow beams: Depending on the beam spread, tighter steps may be needed (e.g., ~1 degree for a 30 degree beam).
- Low output light sources: Exploring and characterizing errors associated with low light sources is needed.

Kevin Dowling, Philips Solid State Lighting, notes that the speed and resolution of photometry is improving—LEDs are driving major advances in art and science of photometry. Dowling highlights two challenges to consider:

- Customer confidence: Consider what allows customers to have confidence in products. How does industry communicate that standards provide confidence?
    - Customers do not trust the numbers now, are making non-technical decisions, and thus are very nervous.
    - Standards are emerging.
    - How do we communicate information about them?
- Push for faster progress on UL:
    - UL8750 is a key part of product listings/sales/use.
    - Meeting every 6 months will not get the job done.
    - DOE and industry groups can put pressure on them and underscore the importance of their efforts.

Fred Welsh, Radcliffe Advisors, emphasizes an underlying point of the Roundtable discussions: With SSL, absolute luminaire measurements are key—measurements cannot be taken at the device level and simply extrapolated to the luminaire. Welsh noted the following areas needing work:

- Understanding of luminaire lifetime
    - Understand failure mechanisms to determine a more complete failure/life test metric.
    - Examine how to establish lifetime (probably not just through lumen depreciation).
- Color issues
    - Examine how the luminaire may change the color of the device and what that may imply for binning.
    - Limit the definition of white within a certain distance of the black body curve.
- Device efficacy standards
    - There are de facto standards among reputable manufacturers, but not trust.
    - Device and package efficacy standards are needed.

Welsh also reminds us that at this early stage in LED technology, we need to be cautious not to limit innovation by being too prescriptive—be careful not to overprescribe procedures as we progress.

Conclusions

The bulleted lists of testing issues and options for solutions underscore the breadth and complexity of challenges facing SSL testing. The measurement standards currently under development were solidly supported and seen as a vital, concrete starting point. The constructive, lively input from all participants highlighted a sense of unity across this diverse set of industry experts—all eager to support SSL testing and take individual actions to move the technologies forward.

A number of specific suggestions will serve to strengthen and further clarify basic integrating sphere and goniophotometry—to be considered for future refinements of LM-79 or for practical guidance associated with LM-79 or LM-80 testing. Other suggestions will be useful for groups working on color-related standards and procedures, or safety-related standards.

The highest priority issues surround standardization of LED device-level testing and reliability testing. Confidence in products will depend on how reliable they turn out to be in the long run. Understanding failure mechanisms at both the LED device level and at the luminaire level (as a whole system) is an important starting point. Clear, repeatable methods are needed for evaluating temperatures at which LED devices are operating in luminaires and cross-checking those temperatures against temperature curves provided by device manufacturers to determine that the devices operate in a safe range *in situ*.

Roundtable participants and stakeholders across the various industry areas (device manufacturers, luminaire manufacturers, testing laboratories, research organizations, trade groups, and standards developers) are encouraged to be aware of the challenges identified here and contribute to solving these issues in the months and years ahead. The wealth of sharing and positive contributions of participants in the Roundtable can set the tone for continued progress in SSL testing.

Appendix

List of Participants

Name	Company
Januk Aggarwal	Holophane
Bob Berger	Independent Testing Laboratories, Inc. (ITL)
Alex Boesenberg	National Electrical Manufacturers Association (NEMA)
Jim Brodrick	US Department of Energy (DOE)
Ronald Daubach	Osram Sylvania
Kevin Dowling	Philips Solid State Lighting
Bob Erhardt	Philips
Kevin Gauna	California Lighting Technology Center (CLTC)
Mike Grather	Luminaire Testing Laboratory (LTL)
Jose Luis Hernandez	Canadian Standards Association (CSA)
Jim Hospodarsky	Acuity Brands Lighting
Andy Jackson	Philips Lighting Company
Dave Jenkins	Orb Optronix, Inc.
Neeraj Lal	Micrel
Jim Leland	Gamma Scientific
Ian Lewin	Lighting Sciences
Li Li	Osram Sylvania (E&C/LED Systems)
Vireak Ly	Southern California Edison (SCE)
Cameron Miller	National Institute of Standards and Technology (NIST)
Mia Paget	Pacific Northwest National Laboratory (PNNL)
Morgan Pattison	National Energy Technology Laboratory (NETL)
Emil Radkov	GE Lumination
Eric Richman	Pacific Northwest National Laboratory (PNNL)
Heidi Steward	Pacific Northwest National Laboratory (PNNL)
Alan Tirpak	Optronic Laboratories, Inc.
Ralph Tuttle	Cree Lighting
Fred Welsh	Radcliffe Advisors
Howard Wolfman	Osram Sylvania - E&C
Yuqin Zong	National Institute of Standards and Technology (Photometry & Colorimetry Group)

DOE SSL CALiPER Roundtable

Bethesda, MD—November 27, 2007

Purpose: Assemble a representative collection of experts to discuss the status of SSL product testing and solicit input and discussion to guide the CALiPER program, to provide input to standards groups, and to suggest additional testing standards needs.

Final Agenda

		Speakers
8:00 am	Welcome & Introductions Quick Update on Standards Activity/Progress Testing Program Progress & Uncertainties	Jim Brodrick (DOE) Eric Richman (PNNL) Mia Paget (PNNL)
8:50	Quick Update on LED Device Level Testing	Yuqin Zong (NIST)
9:15	Workshop Session 1a—SSL Testing Concerns Basic Luminaire Photometric Performance Testing Reliability Testing Lumen Depreciation Testing *In Situ* Testing Device Level Testing (Performance, LM-80, etc.) Other Testing (Glare, Applications, UL, etc.)	*Facilitated Breakout Groups*
10:30	Workshop Session 1b—SSL Testing Specific Issues	*Facilitated Breakout Groups*
Noon	Working Lunch	
1:00 pm	Quandaries: Capability Needs of SSL Testing	*Presentations and Q & A*
	▪ NIST/NVLAP Process & LED Specific Activities	Cameron Miller (NIST)
	▪ Will there be an LED Testing Capabilities Gap?	Heidi Steward (PNNL)
	▪ Q & A Session with Independent Testing Labs	Mike Grather (LTL) Bob Berger (ITL)
2:00	Workshop Session 2—Options, Solutions, Paths Forward	*Facilitated Working Session*
3:30	Wrap-up Panel Key Insights Points of Consensus Remaining Issues Next Steps for Industry, Standards Committees, Testing Labs	*Panel of Experts* --Independent Testing Lab --Manufacturer(s) --Standards Developer --Equipment Manufacturer --DOE
4:30	Closing Words	Jim Brodrick (DOE)
4:45	Adjournment	